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MANUAL FOR UTEP WELD GAS HYDROGEN  
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# INSTRUCTION MANUAL FOR UTEP WELD GAS HYDROGEN DETECTOR

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August 4, 1992

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## I. INTRODUCTION

The instrument described in this manual was developed at the University of Texas at El Paso under contract from the National Aeronautics and Space Administration Marshall Space Flight Center (Contract NAS 8-38662). The instrument has been used to detect hydrogen in the shielding gas of Variable Polarity Plasma Arc (VPPA) welds at concentrations of less than 100ppm. The instrument makes measurements in real time during the welding operation and provides the operator with an easily readable graphic display of the present level of hydrogen in the arc as well as the level of hydrogen over the past approximately five minutes. In this way the welder can not only tell if the present level of hydrogen is excessive, but can see what changes in weld parameters have done to the level of hydrogen.

The welder can set the level of hydrogen that is considered critical and the instrument display will indicate when that level has been exceeded. All detection is from the torch side. All needed equipment is supplied by the developer except for an IBM PC<sup>R</sup> compatible computer which must be supplied by the user.

Source code is supplied in this manual so that the user can modify the control program as desired.

The instrument in its usual operational configuration is shown below.

*END*

ORIGINAL PAGE  
COLOR PHOTOGRAPH



The Hydrogen Contamination Monitor in its usual configuration. Note A welding torch, B lens housing, C fiber optic cable, D filter assembly.

## II. THEORY OF OPERATION

The extreme temperatures (up to 15,000°K) found in welding arcs excite bound electrons in the plasma arc gas to energy levels above the ground state. These excited states follow a Boltzmann population distribution and are typically short lived. When electrons decay from these excited states they emit electromagnetic radiation characteristic of the element.

The amount of hydrogen radiation emitted from a volume element  $\Delta V$  into a detector with solid angle  $\Omega$  is

$$I_{st}(\text{hydrogen}) = \frac{\Omega}{4\pi} \Delta V n_H \frac{g_s e^{-\frac{E_s}{kT}}}{\sum g_i e^{-\frac{E_i}{kT}}} h\nu_{st} A_{st} \quad (1)$$

Where  $n_H$ =number of hydrogen atoms/unit volume

$A_{st}$ = the transition probability from the excited level s to t

$E_s$ =the energy difference between levels s and t

$k$ =Boltzmann's constant

$T$ =absolute temperature

$g_s$ =degeneracy of level s

$h$ =Plank's constant

$\nu_{st}$ =frequency of radiation

The summation is over all states contributing to level s

A similar relation can be written for Argon which has an approximately constant concentration in the arc.

$$I_{mr}(\text{argon}) = \frac{\Omega}{4\pi} \Delta V n_{Ar} \frac{g_m e^{-\frac{E_m}{kT}}}{\sum g_i e^{-\frac{E_i}{kT}}} h\nu_{mr} A_{mr} \quad (2)$$

Dividing (1) by (2)

$$\frac{I_{st}(\text{hydrogen})}{I_{mr}(\text{argon})} = k_1 \frac{n_H}{n_{Ar}} e^{-\frac{(E_m - E_s)}{kT}} \quad (3)$$

where

$$k_1 = \frac{\sum g_i e^{-\frac{E_s}{kT}}}{\sum g_i e^{-\frac{E_m}{kT}}} \frac{A_{st}}{A_{mr}} \frac{\nu_{st}}{\nu_{mr}} \quad (4)$$

If the energies  $E_m$  and  $E_s$  are approximately equal (as they are for H and Argon), Equation 3 indicates that the ratio of the intensity from a hydrogen transition to that from an argon transition is proportional to the percentage of hydrogen in the volume imaged by the detector. Figure 1 shows this ratio as a function of the hydrogen content in the plasma gas for two different currents or temperatures. This data was obtained using a grating spectrometer. Note the minimal temperature effect.

The instrument described in this operating manual uses this principle to detect the concentration of hydrogen. The light from the welding arc is picked up by a focusing lens attached to a fiber optic cable. This light is passed through narrow band interference filters to measure the intensity of the argon (696.5 nm line), hydrogen (656.2 nm line), and background (measured at 670.5 nm). These three separate signals are processed by the computer to

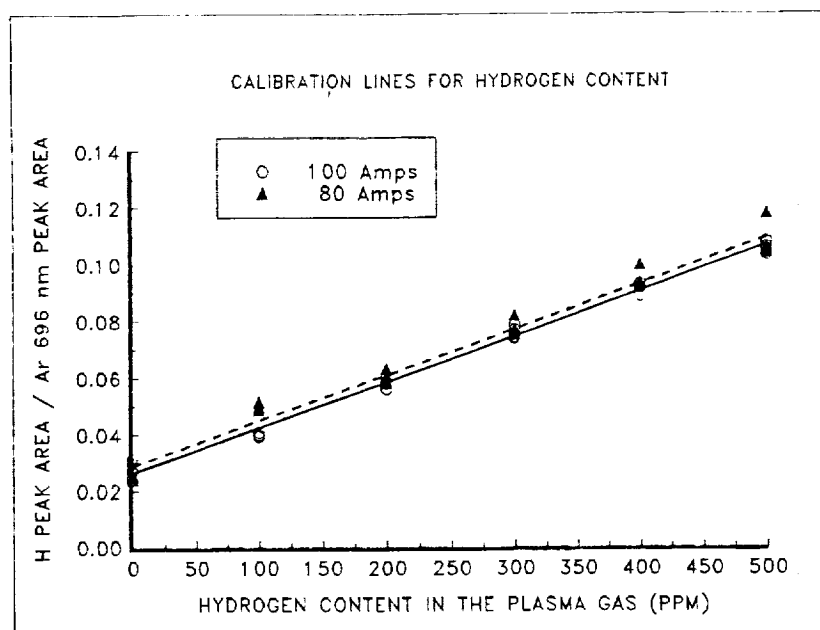


Figure 1 Effect of weld arc current on H/Ar intensity ratio.

calculate

$$\frac{\text{Hydrogen intensity} - \text{Background intensity}}{\text{Argon intensity} - \text{Background intensity}}$$

which is signal averaged and scaled according to Figure 2 which shows this ratio as a function of the concentration of hydrogen in the shield gas. This graph was made by precisely changing the amount of hydrogen in the shield gas during a cover pass using certified purity weld gasses supplied by Scott Specialty Gasses, Houston, Texas.

This ratio is displayed in real time on a computer as a time histogram. See Fig. 3.

Hydrogen and argon intensities change in amplitude with the polarity of the weld torch. Therefore, this instrument is triggered by a voltage obtained from a shunt in the welder ground lead so that it takes data during either the torch negative or positive cycle.



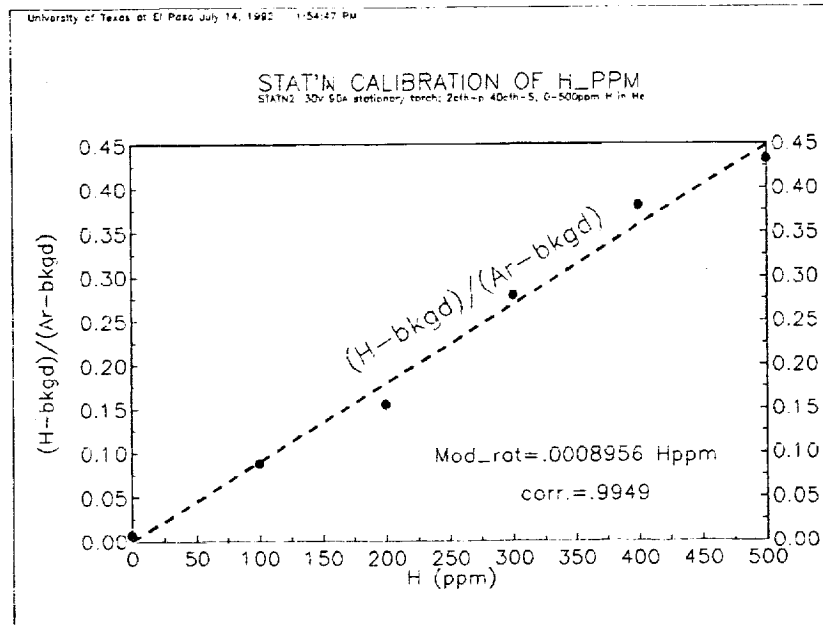
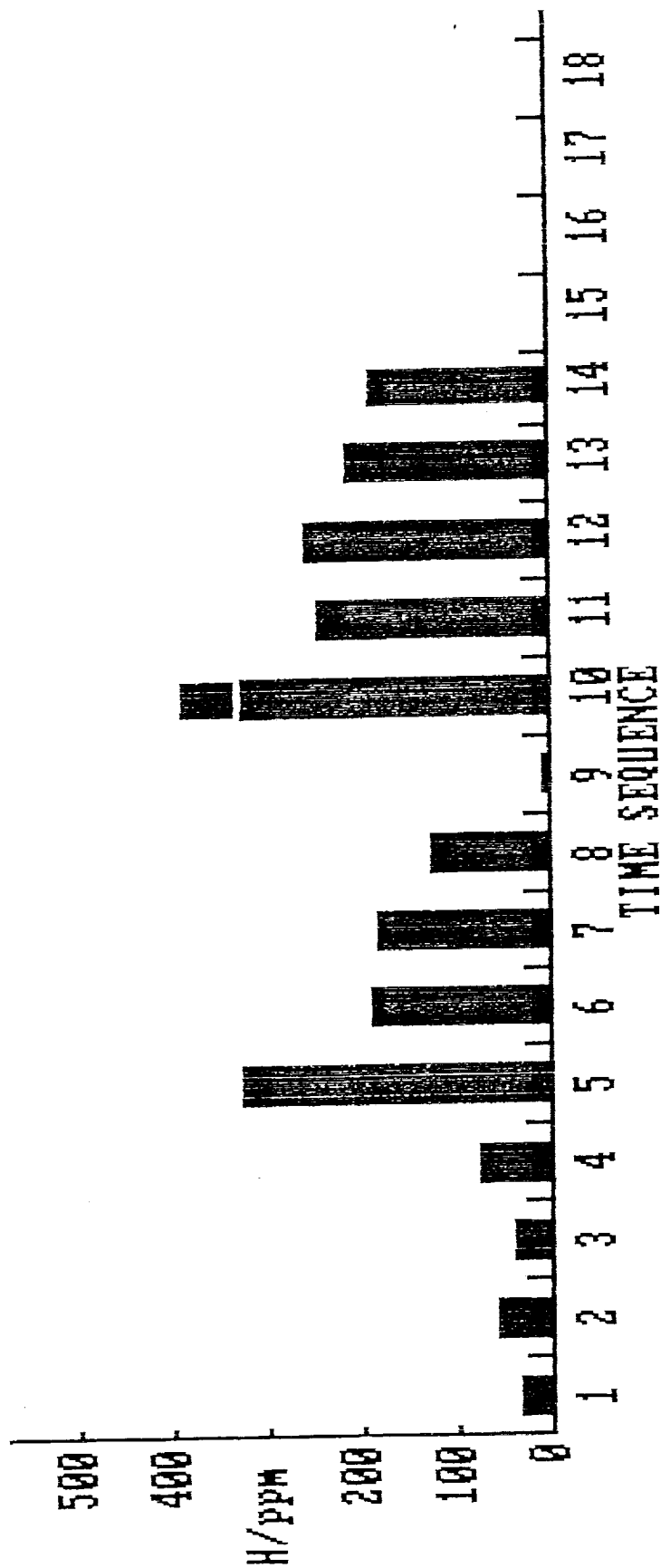


Figure 2 Calibration curve of hydrogen contamination level in shield gas

It should be emphasized that this instrument is calibrated to read the correct level of hydrogen during cover pass welds. Contaminated shield gas during keyhole mode produces a much lower hydrogen signal than during a cover pass and correspondingly produces less apparent degradation of weld quality. This effect is apparently due to flushing the contaminated gas out of the keyhole. The output of this instrument reflects this effect in that even very high levels of hydrogen in the shield gas during keyhole welds give quite low readings for hydrogen.

An unexpected increase in hydrogen level during a keyhole weld may be due to a loss of the keyhole, and the welder should be alert to this possibility.



H (ppm)

Ratio

Volts

Ar 3.79  
Bkg 1.42  
H 1.84

168.8

0.18

Press Any Key to Exit

Figure 3 Output screen of hydrogen monitor. The level of hydrogen was changed by mixing impure gas into the shield gas. Each bar on the histogram represents about 20 seconds. Bars 5, 9, and 10 are not accurate because the gas was being changed during these time periods.

### III. DESCRIPTION OF INSTRUMENT

The Hydrogen Contamination Monitoring System (HCMS) consists of a quartz optical fiber, a lens housing (ORIEL Model #77800), a filter wheel and controller (together comprising Oriel Model 77374), a photodiode (ORIEL Model #71823) and preamplifier (housed in ORIEL Model #71925), A/D boards (Lab Master DMA), trigger interface box, and software. Also included are two 9-volt rechargeable nickel-cadmium batteries, a recharger, one  $\pm 15$  V power supply and the necessary cables.

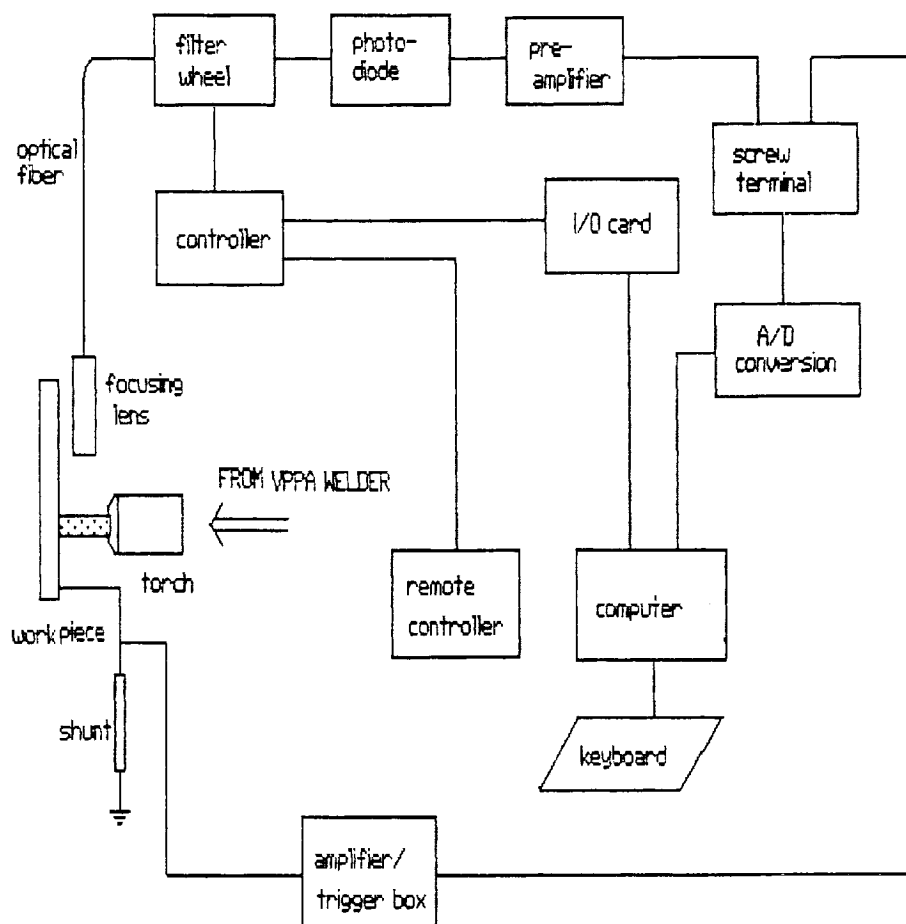


FIGURE 4 SYSTEM CONFIGURATION

Various parts of the instrument will be described separately.

A protective glass, a collimating lens and a focusing lens are mounted in a lens housing at the end of the quartz fiber optic cable which is attached 6 to 8 inches above a welding arc. The motorized filter wheel system consists of a filter wheel and controller, a remote control pad (ORIEL Model 77373) and a computer interface kit (ORIEL Model 77375). The filter wheel has five positions for filters. The first three positions are used for argon, background and hydrogen in the HCMS.

FILTER	POSITION IN THE WHEEL DISK	CENTERED WAVELENGTH	ORIEL MODEL NO.
argon	1	700 nm	53980
background	2	670.8 nm	57250
hydrogen	3	656.2 nm	57230

The filter wheel, remote control and computer interface all interact through the controller to select which wavelength will be detected by the photodiode. The remote control pad is connected to the controller and allows manual selection of the filter position.

The computer interface kit consists of a PC XT/AT or compatible with a parallel I/O port and the appropriate cabling. The I/O card is inserted into one expansion slot of the computer and its base address is 338H. Address selection is performed by positioning two jumpers on the I/O card (see Appendix A).

The silicon photodiode is a light-to-current transducer, mounted in a detector housing with a preamplifier (ORIEL Model

#71925) behind the filter wheel. A BNC connector on the preamplifier conducts a 0 to 10 volt signal to the A/D board screw terminal (terminal block 938532). The gain of the preamplifier can be adjusted by rearranging a switch array inside (see Appendix B). When shipped, it is maximum. A  $\pm 15V$  power supply is connected to the rear panel of the preamplifier.

The A/D board (Scientific Solutions 12-bit PGL) consists of two parts: one board (the daughter board) in its own box and performs the 12-bit A/D conversion while another (the mother board) is inserted directly into a slot of the computer and controls the sampling and external triggering. The base address and the mode of sampling are determined by the configuration of switches, jumpers and connectors shown in Appendix C. Two differential channels 0 and 1 (Channel 0 is pin numbers 39 '+' and 37 '-' on the terminal block for the preamplifier output and Channel 1 is pin numbers 35 '+' and 33 '-' for the external trigger) are used. The 0-to-10V input is chosen (Appendix C).

The amplifier converts the millivolt level signal from the welder ground lead shunt to a TTL pulse. As an external trigger, the amplified signal synchronizes real-time sampling with the variable polarity of the welder. A schematic of the amplifier circuit is illustrated in Figure 5.

Two sockets for Ni-Cd rechargeable batteries are inside the box. On the top, there are two switches: one powers the amplifier and the other (SW below) changes trigger polarity between the electrode positive and electrode negative cycle. The HCMS is

designed for the electrode negative cycle.

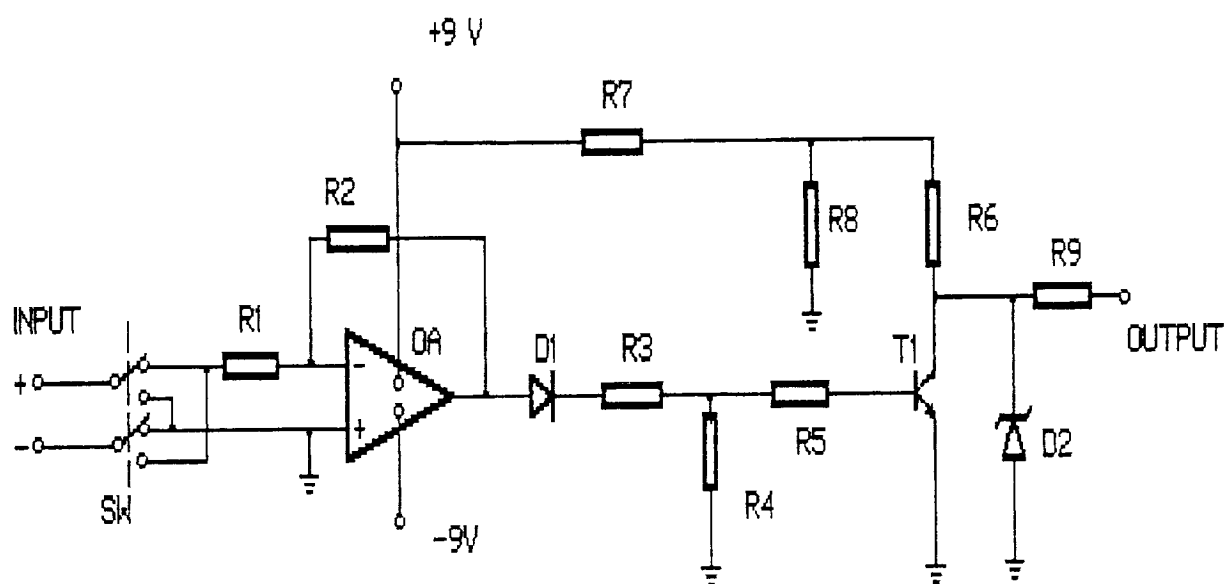


FIGURE 5 Schematic of amplifier circuit.

PARAMETER	COMPONENT	FUNCTION
R1	potentio- meter	R2/R1 is gain of amplifier
R2	220 k $\Omega$	
D1	1N4007	Rectify the waveform output from OA
R3	10 k $\Omega$	Provide $V_{BE}$ of transistor T1
R4	18 k $\Omega$	Provide $V_{BE}$ of transistor T1
R5	1 M $\Omega$	Limit $I_b$ of transistor T1
T1	2N2222A	Separate OA from output circuit; Enhance drive current.
R6	10 k $\Omega$	Determine $I_c$ of transistor T1
R7	5.1 k $\Omega$	Provide voltage supply for T1
R8	6.8 k $\Omega$	Provide voltage supply for T1; Moderate static/dynamic current.
R9	220 $\Omega$	Output current protection
D2	1N750	Output voltage protection
SW	switch	Change input polarity
OA	741 or equivalent	Operational Amplifier. Amplify shunt signal

The HCMS software is written in BASIC to run on GWBASIC V3.22. The software features include menus, data acquisition, and processing, real-time display and histogram display. A simplified flow chart is shown in Figure 6 and the software will be discussed in more detail in Appendix D.

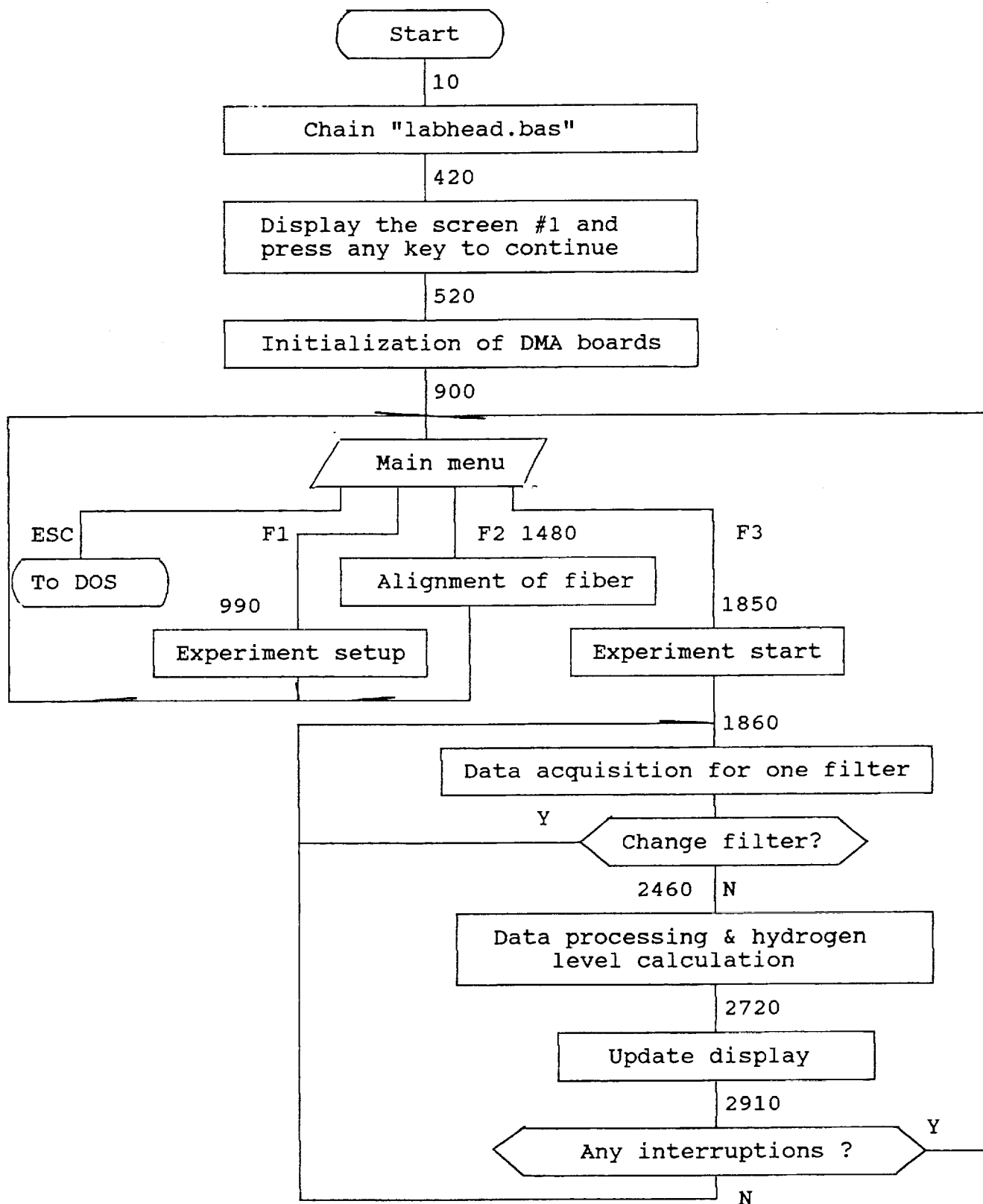


Figure 6 Simplified flow chart of HCMS software with line numbers.



#### IV OPERATION

##### 1. Installation of hardware

Before installation of the system, be sure to turn off the computer and the related devices and ground your hands to remove static electricity. It is best to unplug all devices from wall sockets.

i) Open the computer case and insert the LabPac mother board and the filter-disk drive card into expansion slots of the computer.

ii) Connect J6 (50 pins) on the mother board to P1 on the daughter board, be sure pins 1 correspond to each other and put cover back on the computer.

iii) The 40-conductor ribbon cable connects P2 of the LabPac daughter board to the socket of the screw terminal. The screws 39 and 37 are an analog input from the photodiode, and 35 and 33 are from the output of the amplifier box.

iv) The input of the amplifier box is the shunt signal of the VPPA Welder. Put two rechargeable batteries into their sockets and set the two switches (on the top) to positions "FORWARD" and "ON".

v) Attach the 37-conductor ribbon cable on the filter-disk drive card and 10-conductor ribbon cable on the filter-disk to J1 and J3 of the main controller. If necessary, use the remote control panel linked to J2 of the main controller with a 16-conductor cable. Turn on the main controller and set it to the "COMPUTER" operation mode.

vi) The voltage supply of the photodiode and its amplifier is connected according to the following table.

PIN #	COLOR	FUNCTION	USED
1	brown	External - biased	
2	red	+ 15 volt	*
3	orange	Common	*
4	yellow	- 15 volt	*
5	blue	Frame	
Shield	braid	Frame	

The hardware installation is completed.

## 2. Installation of Software

The real-time software of HCMS is called "HHH.bas". It must be run with "labhead.bas" and under GWBASIC V3.22 or similar environment. The program must be installed the first time as described below. On subsequent uses skip to start from procedure 2 step iii.

The user must run a file "INSTALL.BAT" in a floppy disk. The procedures are as following. The underlined words are input by the user.

i) Turn on your computer and wait for the appearance of the prompt

C >

ii) Insert the program disk into Drive A. Run the file INSTALL.BAT in Disk A:

C > a:install (enter)

iii) Run the program

C > hhh (enter).

The caption screen #1 will appear.

Screen 1

HYDROGEN CONTAMINATION LEVEL  
MONITORING SYSTEM

VERSION 1.1 1992 By

Department of Metallurgical and Materials Engineering

University of Texas at El Paso

(Press Any Key to Continue)

\*\* Hydrogen Detection (c) 1992 by UTEP \*\*

3. Press any key to continue. The main menu (screen #2) will be shown.

## Screen 2

MAIN MENU	
[ESC]	Exit to DOS
F1	Experiment Setup
F2	Align Optical Fiber
F3	Start Experiment

\*\* Hydrogen Detection (c) 1992 by UTEP \*\*

4. Press any one function key F1, F2 or F3 on Screen #2 (main menu) to select a corresponding function from the main menu.

In the menu of EXPERIMENT SETUP (Screen #3), F1 allows the user to identify the actual filter positions. The initial locations are shown on screen #4. Normally the filters are not changed.

## Screen 3

## EXPERIMENT SETUP

[ESC] Exit to Main Menu

F1 Set Filter Positions  
F2 Set A Critical Hydrogen Contamination Level  
F3 Set Display Mode

\*\* Hydrogen Detection (c) 1992 by UTEP \*\*

## Screen 4

## FILTER WHEEL SETUP

[ESC] Exit to Experiment Setup

F1 Position 1 is Ar --- 696.5nm  
F2 Position 2 is BK --- 670.5nm  
F3 Position 3 is H --- 656.2nm  
F4 Position 4 is  
F5 Position 5 is

Please input the maximum filter number ? 3

\*\* Hydrogen Detection (c) 1992 by UTEP \*\*

After pressing F2 (Screen #3), you can input a critical hydrogen contamination level in ppm on Screen #5. This value will provide an over-limit warning by changing the color of the histogram.

## Screen 5

Please input a critical Hydrogen Contamination Level  
( 0 - 500 ppm)?

\*\* Hydrogen Detection (c) 1992 by UTEP \*\*

"DISPLAY MODE SETUP" follows Screen #3 when F3 is pressed  
(see Screen #6).

## Screen 6

## DISPLAY MODE SETUP

F1     Color

F2     Black/White

\*\* Hydrogen Detection (c) 1992 by UTEP \*\*

5. F2 on Screen #2 (main menu) facilitates alignment of the optical fiber. Make sure that the argon filter is in position on the filter wheel (Screen #7). Adjust the lens housing slightly until the statistical readout of the amplified photodiode reaches between 4.0 and 9.5 volts. If not, Screen #8 will not be displayed and "Too

Small" or "Over-Limit" prompts appear. Best results have been obtained with the lens housing 15 to 20 cm from the torch. The lens must have an unobstructed view of the arc.

#### Screen 7

Alignment based on the Ar line  
Please make sure WHICH position is Ar Filter (1 - 5): ?1

\*\* Hydrogen Detection (c) 1992 by UTEP \*\*

#### Screen 8

Readout from Ar Filter : 6.542 Volts

Average : 6.497 Volts

WELL DONE! Please press any key to continue

\*\* Hydrogen Detection (c) 1992 by UTEP \*\*

6. Return to the main menu (Screen #2) to start the experiment. Check the voltage supplies and make sure they are ON. Press F3 and an updated histogram will be displayed in real-time. If the alignment of the lens housing changes so that the intensity of the

argon line is beyond the range of the photodiode or is too low for accurate results, a box appears on the output screen around the level of argon. This will alert the welder to this condition.



## V TROUBLESHOOTING

Trouble free operation of the instrument is expected but should difficulties arise try the following steps.

1. Verify that the photodiode and its amplifier are working properly by putting a voltmeter across its output BNC terminals. When the torch is on, it should be possible to adjust the position of the lens assembly to obtain a 10V signal. Be sure that the power supplies are "ON". If not, check the operational amplifier in the photodiode amplifier and be sure that the fibers in the fiber optic cable are not broken. Care should be taken in handling the fiber.

2. Verify that the shunt in the welder ground line is putting out a signal of at least 50 mv during its positive cycle and that the amplifier is putting out at least 3.0 v. Check the batteries and other components in the amplifier if the output signal is too low.

3. If the instrument still does not work, run the fiber alignment option from Screen 2 and examine the value of the readout "AVERAGE" on the screen. It should be approximately 9.997 v when the fiber is aligned for maximum signal. If it is not, there may be a problem in the analog to digital conversion boards.

4. Since any hardware interrupts (include keyboard interrupts) are prohibited while sampling, reset the system when the program stops at the Screen displayed as "Now is Sampling ... ..". Check for good connections and powers-on, and then start the experiment

again.

The fiber optic cable should be rigidly attached to the torch. Small variations in its position can make large changes in output. Make sure that the fibers are not broken in the fiber optic cable bundle by looking at one end with the other end illuminated. The loss of one or two fibers will not effect the operation greatly.

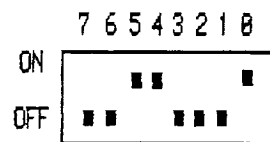
Occasionally clean the protective glass in the lens housing of the fiber optic cable.

No problems with RF pickup have been encountered, but they are always a possibility. Try adjusting the position of the computer if such problems are suspected.

## VI APPENDICES

## APPENDIX A Switch array of the filter wheel drive card

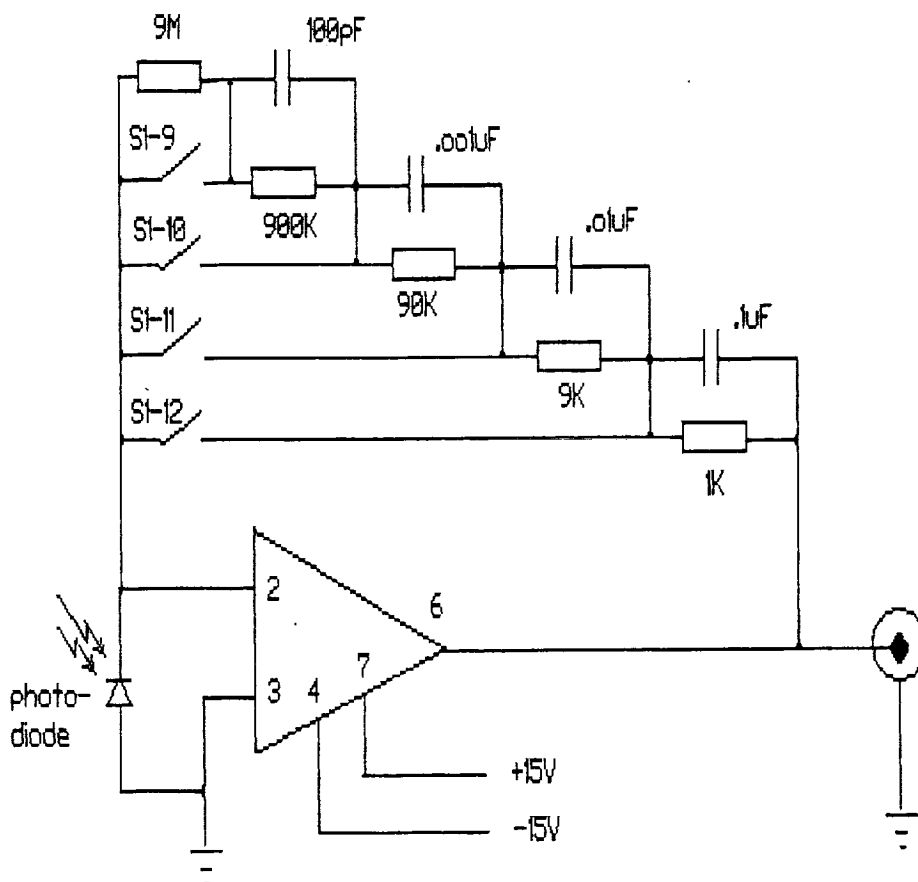
BASE ADDRESS



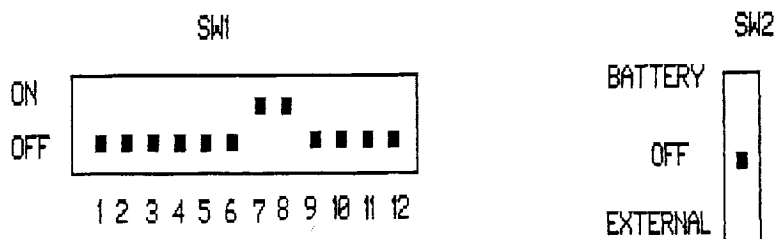
J2



# APPENDIX B      Switch array of the preamplifier

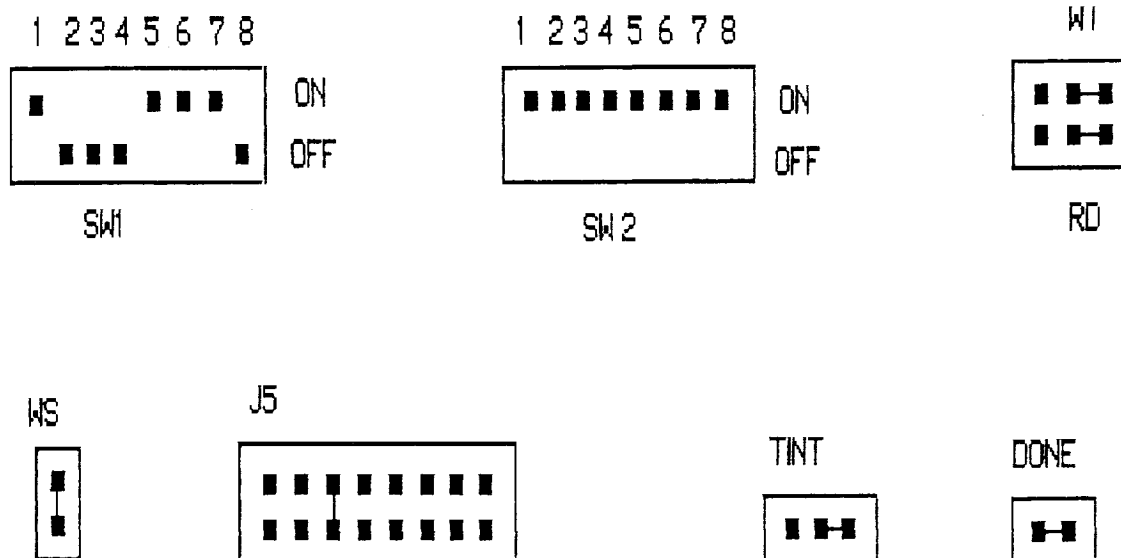


## Amplification mechanism of preamplifier

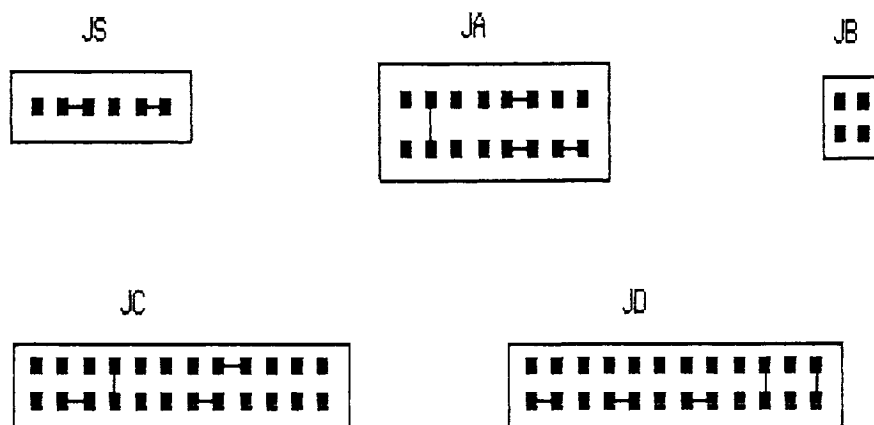


Switch setup on the preamplifier.

# APPENDIX C Configuration of Lab Master boards



The settings of switches and connectors on the mother board.



The settings of connectors on the daughter board.

## APPENDIX D      Explanation of software

With HCMS you can

- . set display mode.
- . perform real-time sampling of hydrogen levels in the  
welding arc.
- . perform statistical analysis.
- . drive the filter wheel to select an appropriate  
position.
- . align the optical fiber off-line.
- . display data and a histogram of hydrogen level.

all within a menuing environment.

## 1. Several Important Program Variables

VARIABLES	VALUES	LINE NUMBER	SIGNIFICANCE
CHN	1		Trigger box output connected to channel 1
FILTERNO	1 to MAX		Present position on filter disk
FLAG1	0		Without scrolling the histogram
	NOT 0		Flag of scrolling the histogram
FLAG2	0		Color display mode
	1		Black/White display mode
FINISH	1100	2050	Post-trigger point (for AISC)
MAX	3		Maximum # of filters
MAXL	80		Width of a screen; # of characters each line
MAXT	17		Maximum #(18) of displayed histogram bars
NCHANS	1	2060	Filter output connected to channel 0
START	300	2050	Pre-trigger point (for AISC)
WARNFL	0		Argon intensity is between 4.0 and 9.5 volts
	1		Less than 4.0 volts or greater than 9.5 volts warning flag of argon intensity
Y0	300	620	Critical hydrogen contamination level

Be sure that each battery can output over 7.0 volts. The required values of START and FINISH are affected by the low battery voltage.

## 2. Calibration Curve for Hydrogen Concentration

The expression in line 3740

$$\text{HPPM!} = -182.12 + 2068.68 * \text{RATIO!}(P)$$

is an experimental curve. It is used to calibrate hydrogen contents under 500 ppm in a contaminated shield gas during cover pass mode.  $RATIO!(P)$  is the H/Ar ratio from the photodiode and  $HPPM!$  is the calibrated hydrogen content in ppm.

### 3. Signal Averaging

To improve that statistics on the photodiode response, its value is read on a number of consecutive cycles of the welder. The number of cycles that it reads and later averages is `SAMPLE` in line 670 and later used in line 2040.

The default value is 100. A quicker instrument response can be obtained at slightly worse signal to noise ratio by decreasing the value of `SAMPLE`.

### 4. Important LabPac Functions

LabPac functions are a software support system designed for use with Scientific Solutions' Lab Master DMA boards. The modular construction is adopted, i.e. the functions are relatively independent. Each of them contains its own input parameters programmable to users. The important LabPac routines used for the HCMS application will be illustrated next.

**AISC:** LABPAC (`CHN`, `START`, `FINISH`, `RESULT`, `AISC`) line 2050. This command reads a signal coming from the shunt and the program pauses here until the signal that it reads changes its digital value from less than `START=300` to greater than `FINISH=1100`. This line insures that data collection is from the same cycle as the switch position on the amplifier box.

**AIMAX:** LABPAC (`SWTIMER`, `NSWEEPS`, `NCHANS`, `AICHAN(0)`, `AIBUFF(0)`,



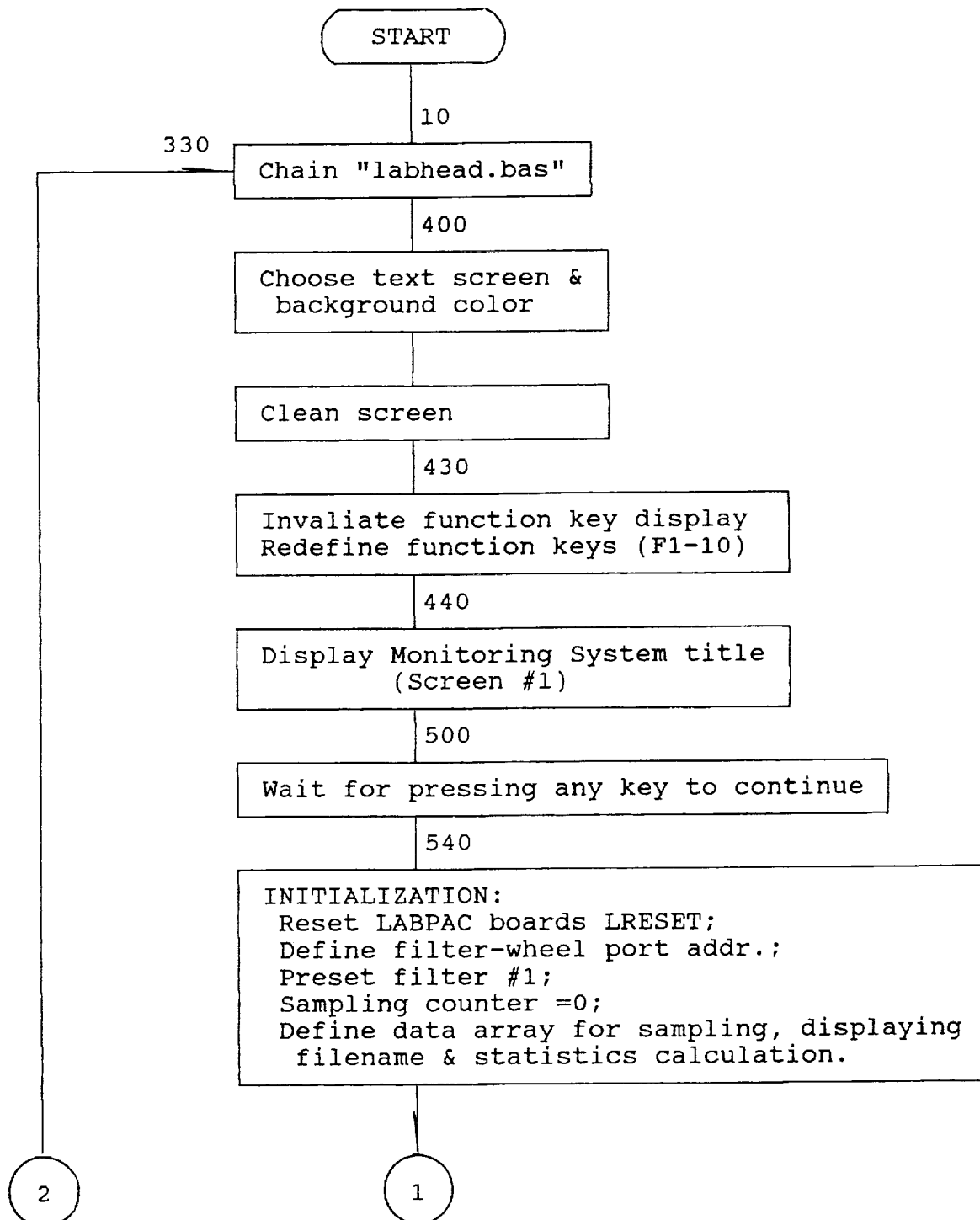
RESULT, AIMAX) line 2080. The main data from the photodiode is taken in this line. NSWEEP (the default value is 200) samples are taken and stored in the array AIBUFF(). The rate at which these samples is taken is controlled by the TIST command. The default rate is 10 khz.

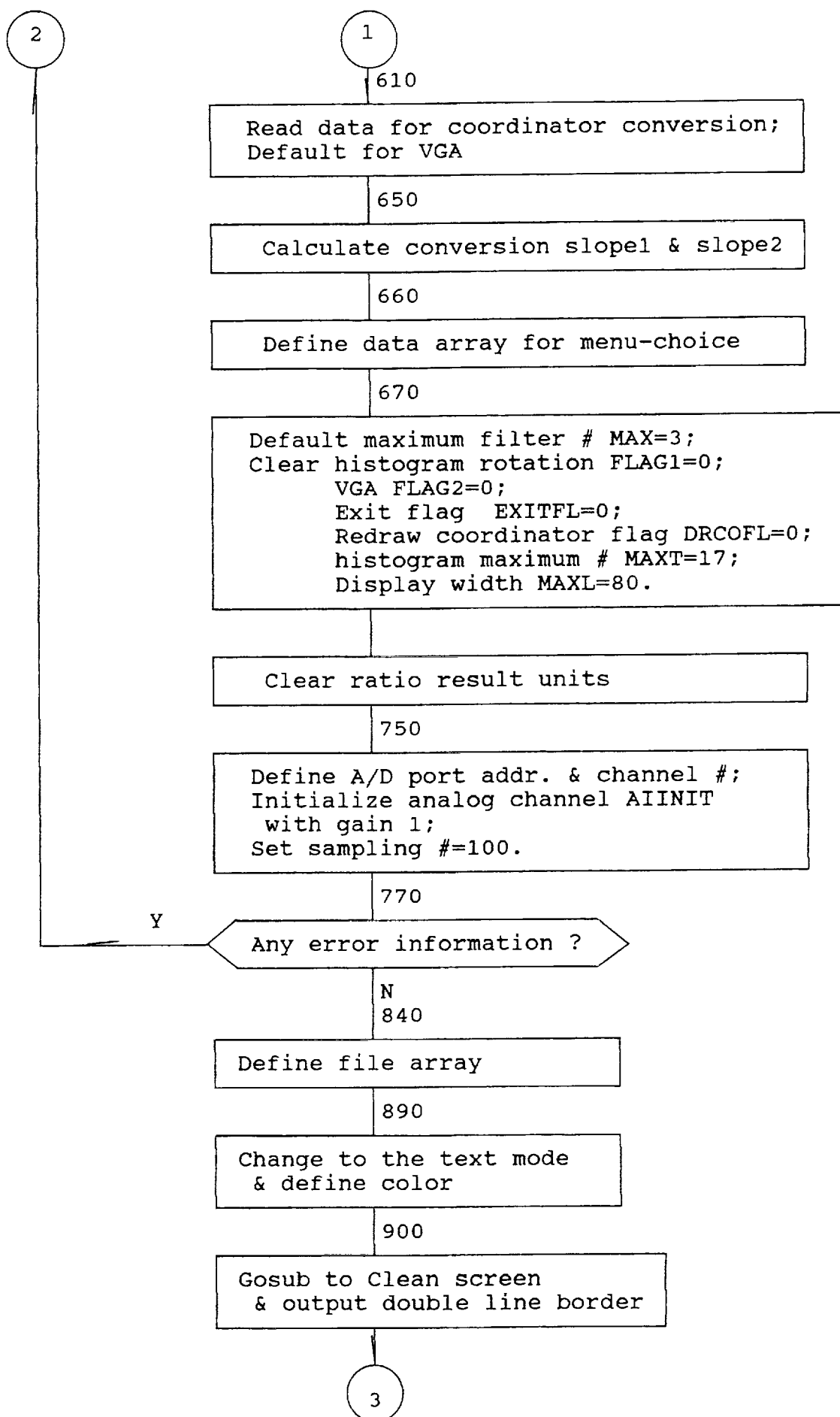
Line 2100 picks out the 90th sample from the array AIBUFF() and stores it in DATA(). Since there is a small change in the emission level during the forward and reverse cycles of the welder, the instrument is designed to take a sample in the approximate middle of the forward cycle where the variation is least. This value is accumulated and averaged over SAMPLE=100 (line 670) cycles to obtain a best value of the photodiode response. The instrument is designed for a 19 msec forward cycle. If the forward cycle is lengthened, there should be a proportional increase in the sample number that is picked out for averaging. For example, if the forward time is changed to 38msec, the 180th sample should be picked out instead of the 90th sample. For small changes in the cycle length, however, no program changes are needed.

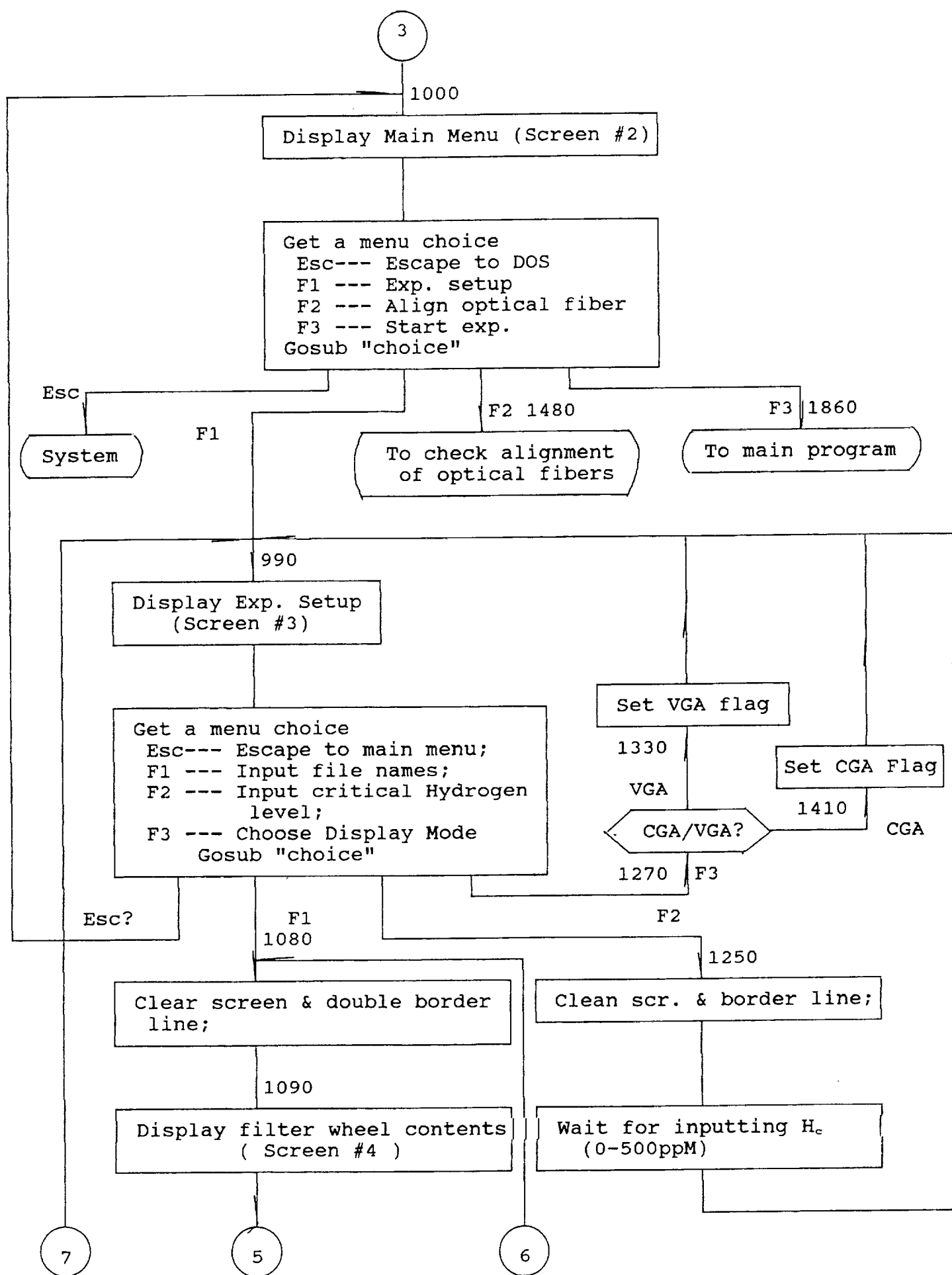
TIST: LABPAC (SWTIMER, MODE, VALUE, RESULT, TIST) line 2030. This line sets the rate at which data is sampled in AIMAX in line 2080. The rate at which data is sampled depends on the MODE and VALUE in line 2020. See accompanying table.

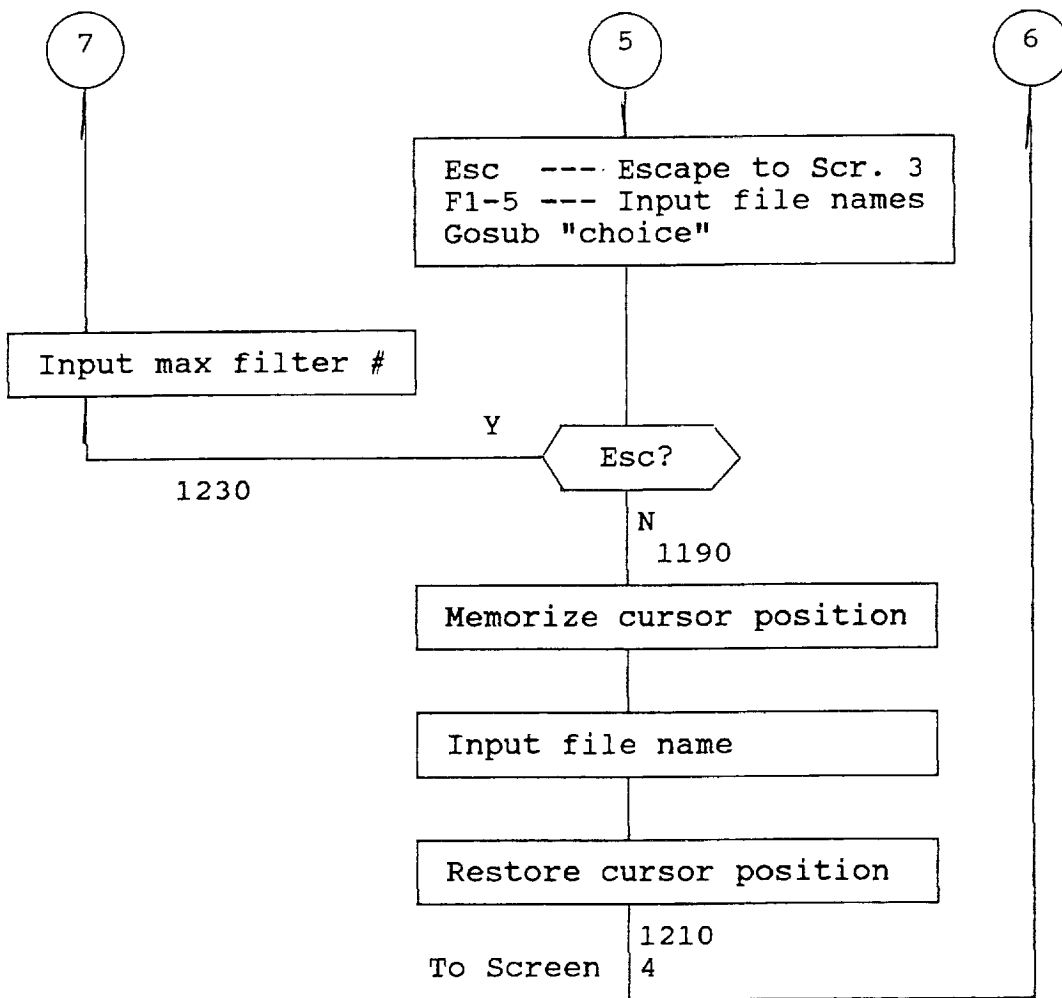
MODE	SAMPLING FREQUENCY (Hz)	
	VALUE =1	VALUE=10
11	1 M	100 k
12	100 k	10 k
13	10 k	1 k
14	1 k	N/A
15	N/A	N/A

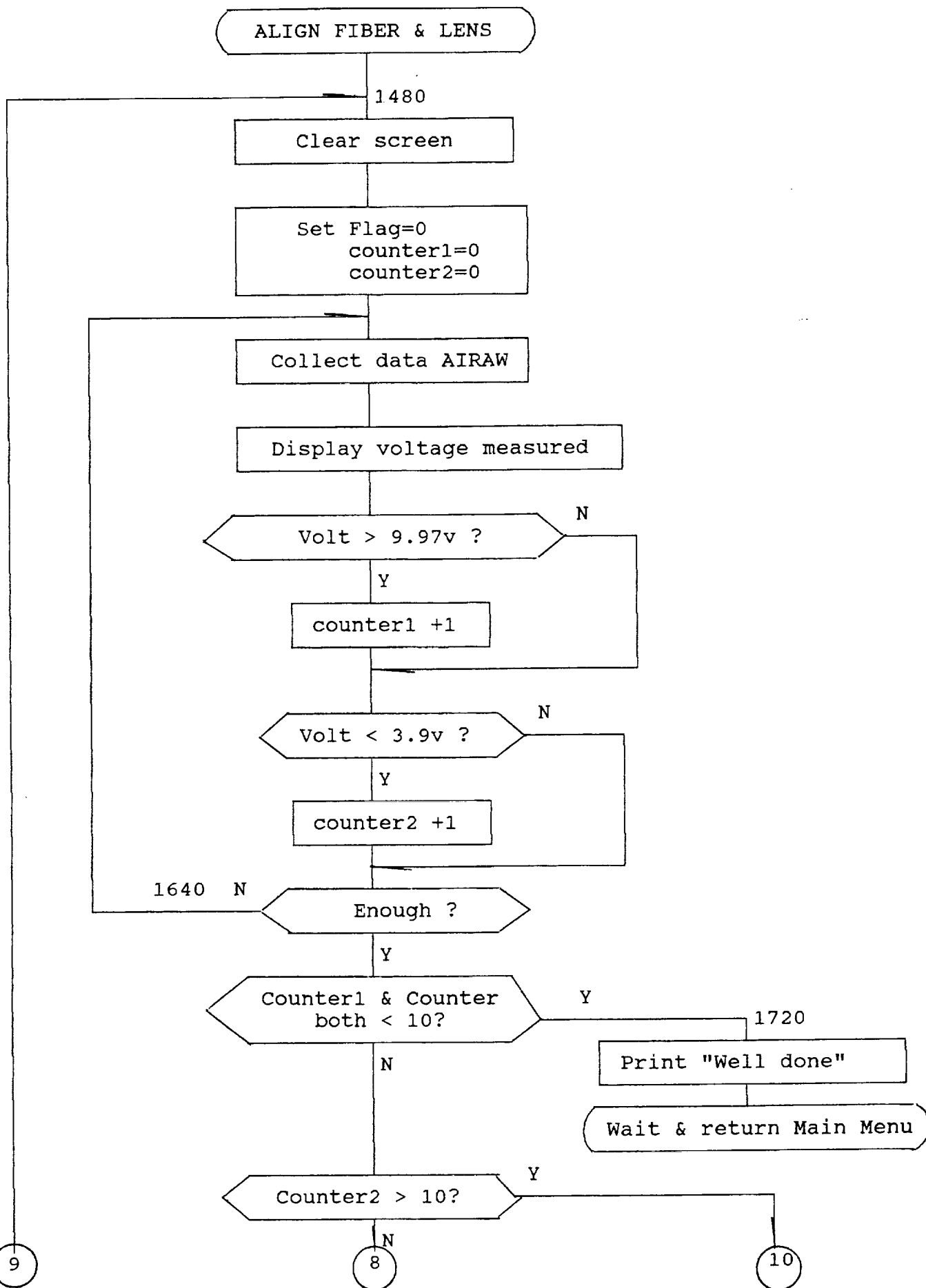
## APPENDIX E Flow Chart of Program

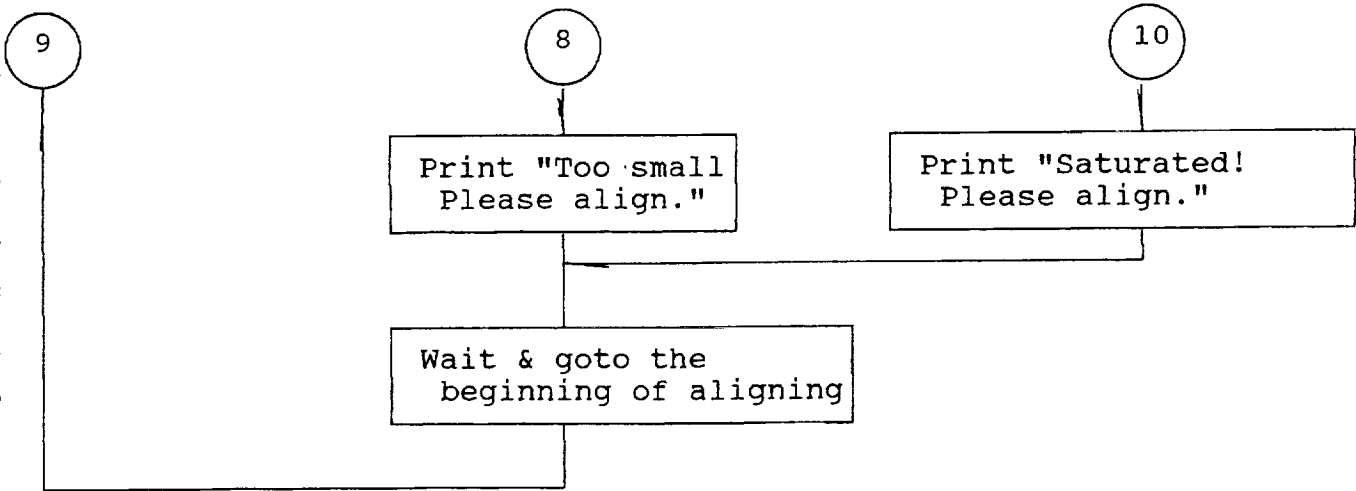




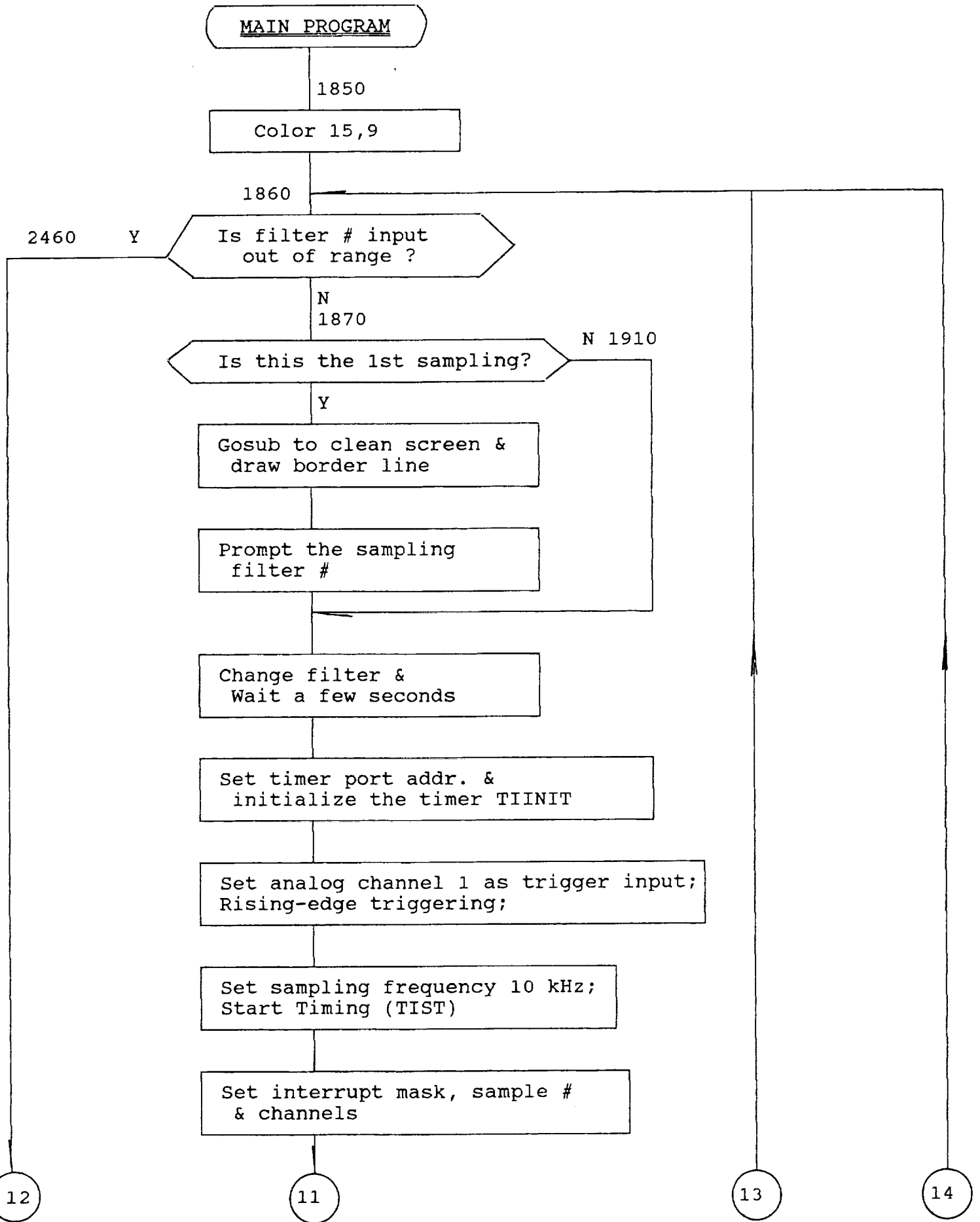












12

11

13

14

Masking interrupt INTCLR  
Sampling under external trigger  
AIMAX  
Clear interrupt flag INTSET

Obtain 9 ms sampling data and  
transfer to a new data array  
DDDD(I)

Statistics:  
Clear SUM unit

Get SUM of total samples;  
Calculate AVERAGE;

Clear STANDARD DERIVATION unit

Calculate SIGMA

Display computed results

Store AVERAGE to present unit  
pointed by p

Next filter

Finished a group of sampling ?

N

Y

Reset #1 filter

Ar(p)-Li(p) > .1 volts ?

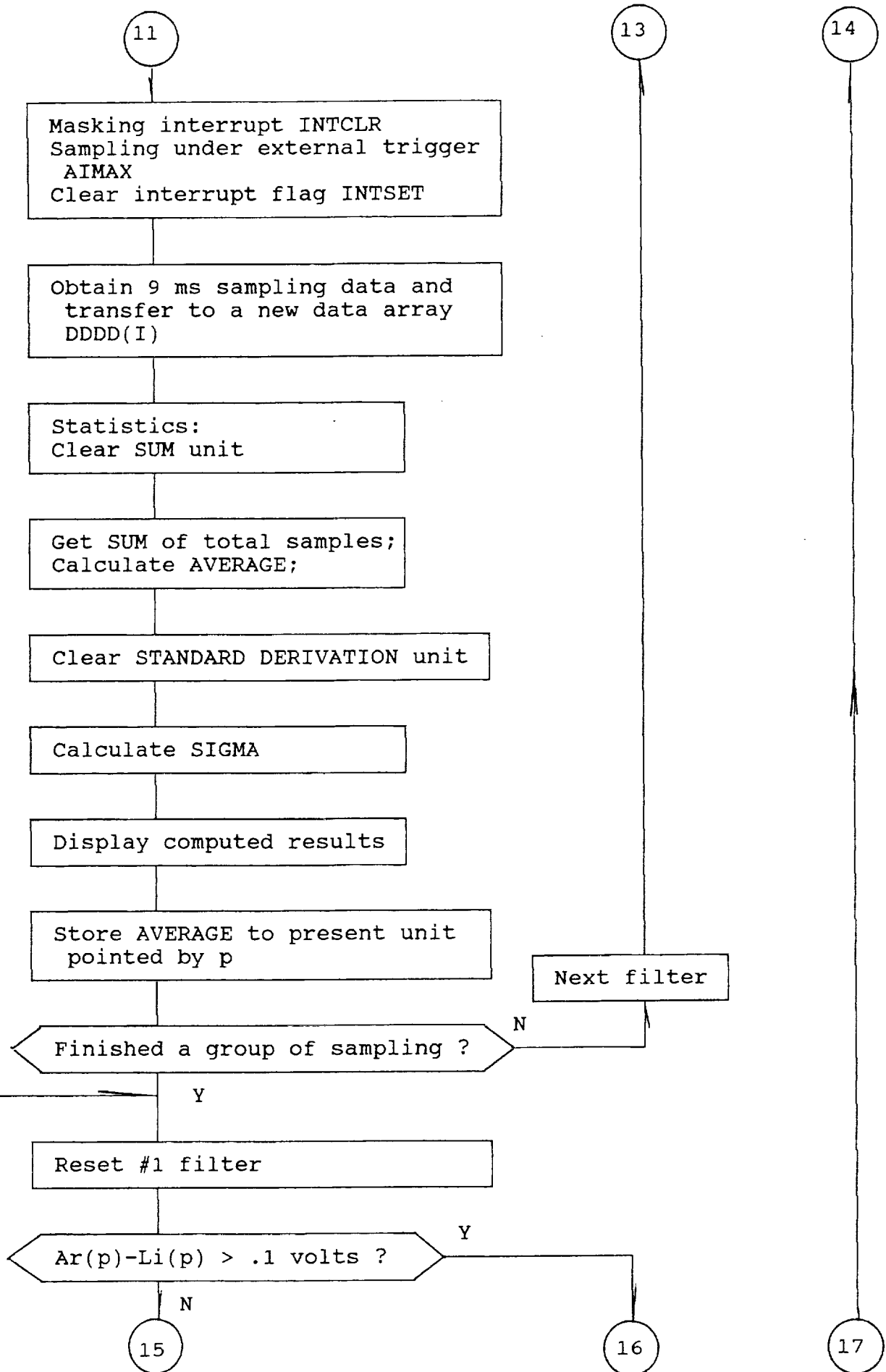
Y

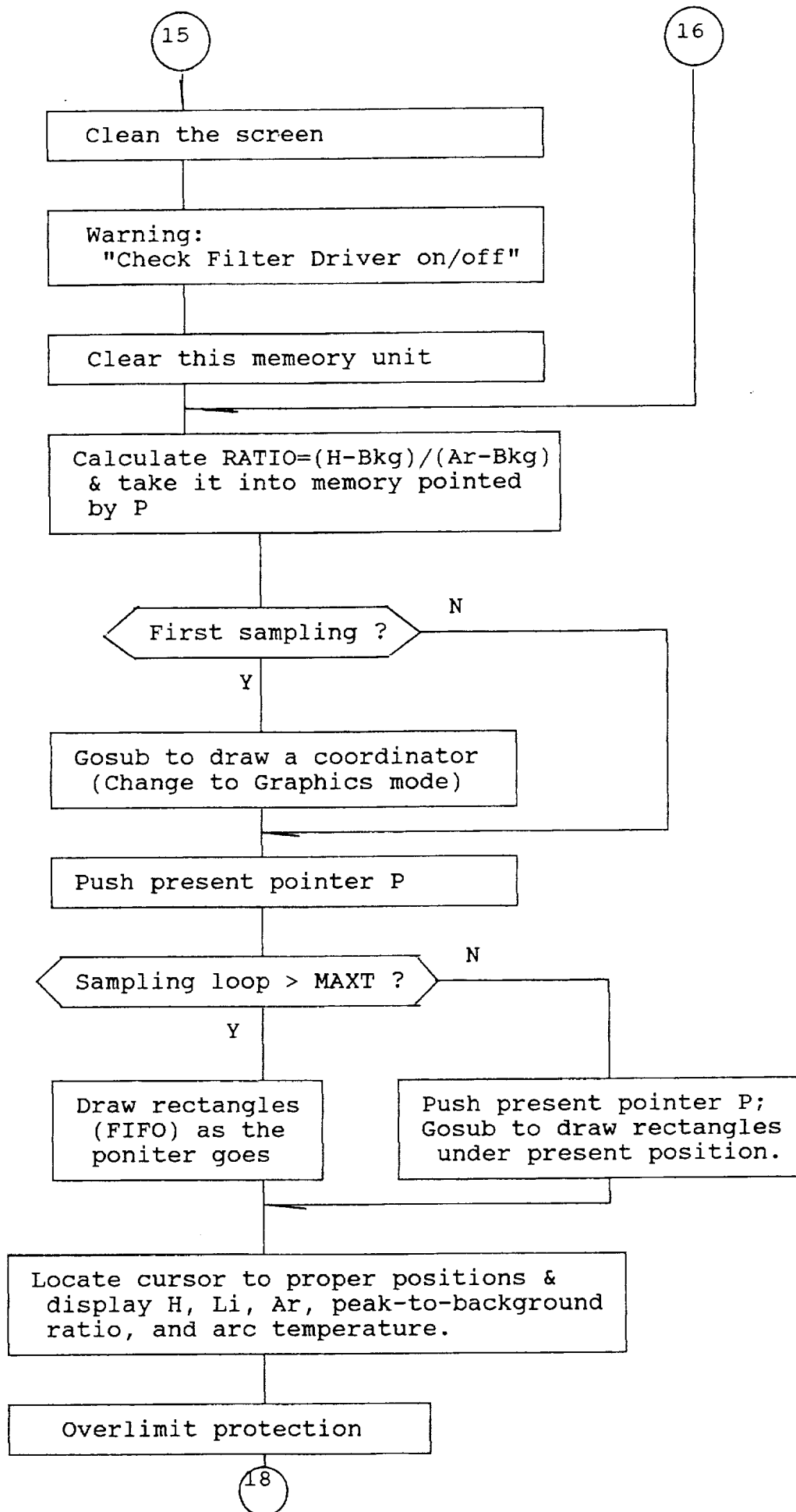
N

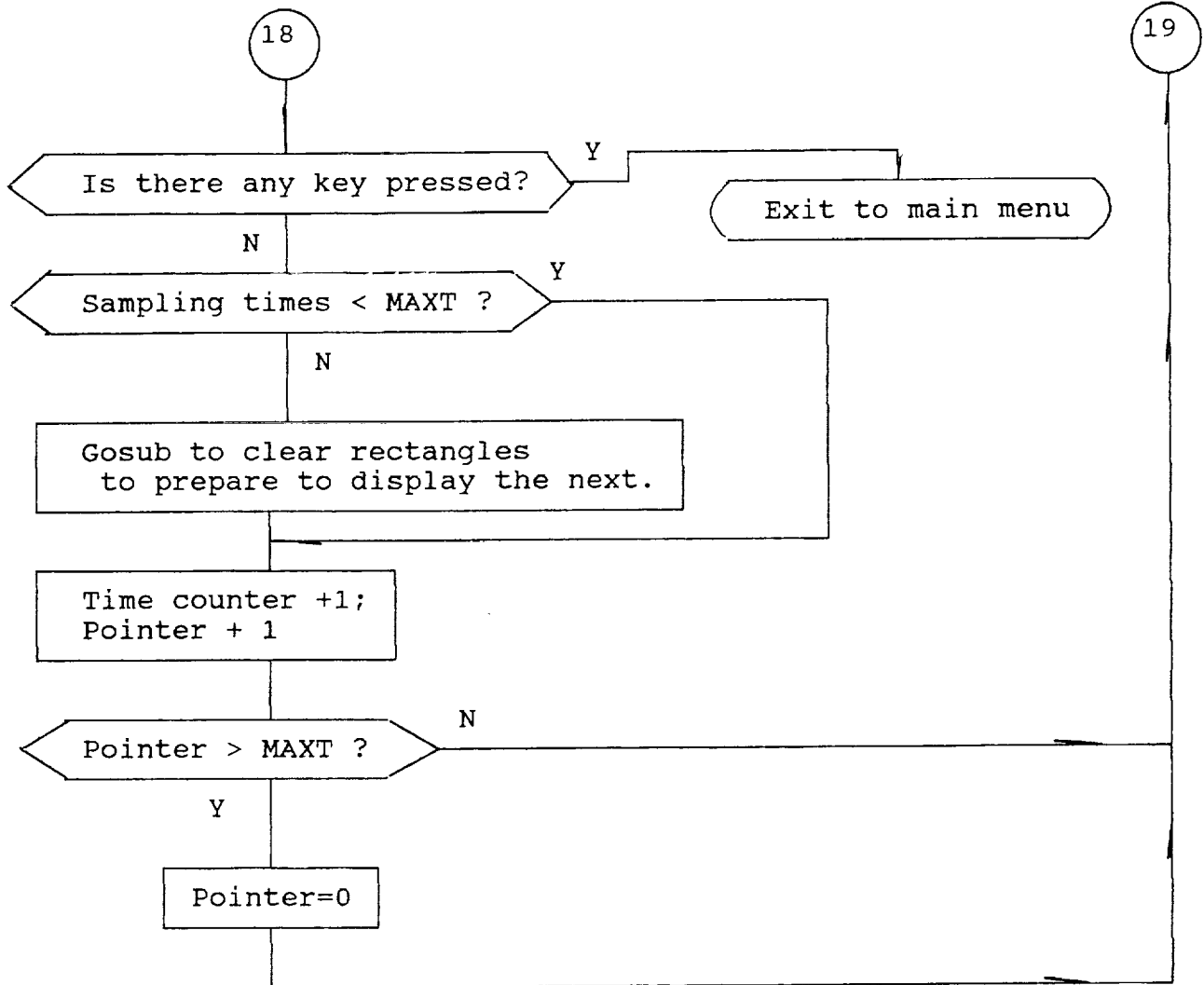
15

16

17







## APPENDIX F Program Listing

```

1 /
2 /           Caption screen display
3 /
4 MASTER%=1
10 CHAIN MERGE "labhead.bas",A
400 SCREEN 0, 1
410 COLOR 15,9
420 GOSUB 3050      ' Clean Screen
430 KEY OFF: FOR I=1 TO 10: KEY I,"" :NEXT
440 LOCATE 6, 26:PRINT"HYDROGEN CONTAMINATION LEVEL
450 LOCATE 7, 26:PRINT"           MONITORING SYSTEM           "
460 LOCATE 10,26:PRINT"   VERSION 1.1   1992   By"
470 LOCATE 15,14:PRINT"Department of Metallurgical and Materials
Engineering
480 LOCATE 17,24:PRINT"University of Texas at El Paso"
490 LOCATE 22, 27:PRINT"(Press Any Key To Continue)"
500 IF INKEY$ <> "" THEN 510 ELSE 500
510 /
520 /           Initialization
530 /
540 RESULT=0

550 CALL LABPAC(RESULT, LRESET)
560 PORTADDR=&H338 'I/O drive card address
570 FILTERNO=1: TIMES=0 'FILTERNO--Filter position
580 DIM GAIN(1), AIBUFF(500), DDDD(100), AICHAN(2), WL$(5),
V!(200), RD(120)
590 DIM AR!(20),LI!(20),H!(20), RATIO!(20), RATIO2!(20): P=0
600 DIM ARE!(20),LIE!(20),HE!(20), RATIOE!(20)
610 READ XLEFT,XRIGHT,YBOT,YTOP, XSTEP,YSTEP,Y0
620 DATA 51,308,162,20,32,16,300
630 READ XL,XR,YB,YT, YST, YMAX2, YMIN2, Y210
640 DATA 546, 554, 313, 200, 16, 14000, 9000, 201: ' thermometer
coord.
650 YSL!=(YT-YB)/(YMAX2-YMIN2) 'coordination conversion
660 DIM SWEEPS(3), STAT(3)
670 MAX=3: ARPOS=1: FLAG1=0: FLAG2=0: EXITFL=0: DRCOFL=0: MAXT=17:
MAXL=80: SAMPLE=50 'MAX--total # of filters; ARPOS--Ar filter
position; FLAG1-- ; FLAG2--Color/B&W display mode; EXITFL--exit
flag; DRCOFL--redrawing histogram coord. flag
680 P=0
690 P1=P
700 FOR P=0 TO 7
710 RATIO!(P)=0
720 NEXT
730 P=P1
740 /

```

```

750 ATOD=&H714: CHANNELS=2: DMA=0: GAIN(0)=0: GAIN(1)=0 'ATOD--A/D
board address; CHANNELS--analog input channel #
760 CALL LABPAC(ATOD, CHANNELS, DMA, GAIN(0), RESULT, AIINIT)
'initial analog input channel
770 IF RESULT <> CHANNELS THEN GOSUB 330
780 '
790 '
800 '
810 '
820 '           Menus
830 '
840 WL$(1)=" Ar --- 696.5nm"
850 WL$(2)="Bkg --- 670.5nm"
860 WL$(3)=" H --- 656.2nm"
870 WL$(4)="
880 WL$(5)="
890 SCREEN 2,1: SCREEN 0,2: COLOR 15,9
900 GOSUB 3050
910 LOCATE 7, 32:PRINT"MAIN MENU
920 LOCATE 10, 25: PRINT"[Esc]   Exit To DOS
930 LOCATE 12, 26: PRINT" F1     Experiment Setup
940 LOCATE 13, 26: PRINT" F2     Align Optical Fiber"
950 LOCATE 14, 26: PRINT" F3     Start Experiment"
960 HIGH=3: GOSUB 3250          ' get menu choice
970 IF CHOICE=0 THEN SYSTEM
980 ON CHOICE GOTO 990, 1480, 1860
990 GOSUB 3050
1000 LOCATE 8, 30:PRINT"   EXPERIMENT SETUP
1010 LOCATE 11,25: PRINT"[Esc]   Exit To Main Menu
1020 LOCATE 13,20: PRINT"F1     Set Filter Positions"
1030 LOCATE 14,20: PRINT"F2           Set A Critical Hydrogen
Contamination Level"
1040 LOCATE 15,20: PRINT"F3     Choose Display Mode"
1050 HIGH=3: GOSUB 3250
1060 IF CHOICE=0 THEN 890
1070 ON CHOICE GOTO 1080, 1250, 1270
1080 GOSUB 3050
1090 LOCATE 8, 30:PRINT"   FILTER WHEEL SETUP
1100 LOCATE 11,25: PRINT"[Esc]   Exit To Experiment Setup
1110 LOCATE 13,26: PRINT"F1     Position 1 is ";WL$(1)
1120 LOCATE 14,26: PRINT"F2     Position 2 is ";WL$(2)
1130 LOCATE 15,26: PRINT"F3     Position 3 is ";WL$(3)
1140 LOCATE 16,26: PRINT"F4     Position 4 is ";WL$(4)
1150 LOCATE 17,26: PRINT"F5     Position 5 is ";WL$(5)
1160 HIGH=5: GOSUB 3250
1170 IF CHOICE=0 THEN 1230
1180 ON CHOICE GOTO 1190, 1190,1190,1190,1190
1190 LOCATE 13+(CHOICE-1),48: ROW=CSRLIN: COL=POS(0)
1200 LOCATE 19,18: PRINT"Position";CHOICE;"is ";; INPUT WL$(CHOICE)
1210 LOCATE ROW,COL: PRINT"
1220 GOTO 1110
1230 LOCATE 19,35:PRINT"

```

```

"
1240 LOCATE 19,18: PRINT" Please input the maximum filter number
";:INPUT MAX: GOTO 990
1250 GOSUB 3050
1260 LOCATE 10,12: PRINT"Please input a critical Hydrogen
Contamination Level": LOCATE 13,26: PRINT"(0-500 ppm)";: INPUT Y0:
GOTO 990
1270 GOSUB 3050
1280 LOCATE 11,25: PRINT"F1      Color
1290 LOCATE 13,25: PRINT"F2      Black/White
1300 MAXT=17: MAXL=80
1310 HIGH=2: GOSUB 3250
1320 ON CHOICE GOTO 1410, 1330
1330 FLAG2=1
1340 RESTORE 1360
1350 READ XLEFT,XRIGHT,YBOT,YTOP, XSTEP,YSTEP,Y0
1360 DATA 51,308,92,4,32,16,300
1370 READ XL,XR,YB,YT, YST, YMAX2, YMIN2, Y210
1380 DATA 546, 554, 175, 115, 16, 14000, 9000, 116
1390 YSL!=(YT-YB)/(YMAX2-YMIN2)
1400 GOTO 990
1410 FLAG2=0
1420 READ XLEFT,XRIGHT,YBOT,YTOP, XSTEP,YSTEP,Y0
1430 RESTORE 1450
1440 DATA 51,308,162,20,32,16,300
1450 READ XL,XR,YB,YT, YST, YMAX2, YMIN2, Y210
1460 DATA 546, 554, 313, 200, 16, 13000, 9562, 201
1470 GOTO 990
1480 '
1490 '      Aligning fiber and lens
1500 '
1510 GOSUB 3050: LOCATE 11,26: PRINT"Alignment is based on the Ar
line.
1520 LOCATE 13,16: PRINT"Please make sure Which Position is Ar
Filter (1-5):";:INPUT ARPOS
1530 POSITION=FILTERNO: FILTERNO=ARPOS
1540 GOSUB 3900 'set the argon filter in position
1550 FOR I=0 TO 24000: NEXT 'wait for turning the filter wheel
1560 GOSUB 3050
1570 FLAG=0: COUNT1=0: COUNT2=0: SUM!=0 'COUNT1--too-high sample
counter; COUNT2--too-low sample counter; FLAG--statistic over-range
flag
1580 FOR I=0 TO 119
1590 CH=0: CALL LABPAC(CH, RD(I), AIRAW) 'sampling; CH--sampling
channel; RD(I)--sampling result unit
1600 SUM!=SUM!+RD(I)/409.6
1610 LOCATE 7,22: PRINT USING "#.###";RD(I)/409.6;: PRINT"
Volts",:PRINT "Average=";:PRINT USING "#.###";SUM!/(I+1)
1620 IF RD(I) >=4090 THEN COUNT1=COUNT1+1
1630 IF RD(I)<=1600 THEN COUNT2=COUNT2+1
1640 NEXT
1650 LOCATE 12,5:PRINT"

```

```

1660 LOCATE 13,5:PRINT"
1670 LOCATE 14,5:PRINT"

1680 IF COUNT1 <= 10 AND COUNT2 <= 10 THEN 1720
1690 IF COUNT2 > 10 THEN 1710
1700 LOCATE 13,17:PRINT" Signal SATURATED! Please ALIGN the
fiber.": GOTO 1740
1710 LOCATE 13,17:PRINT" Signal TOO SMALL! Please ALIGN the
fiber.": GOTO 1740
1720 LOCATE 12,25:PRINT" OK! Well Done."
1730 LOCATE 14,15:PRINT" Please Press Any Key To Return Main Menu":
IF INKEY$ <> "" THEN 1760 ELSE 1720
1740 FOR I=0 TO 3000: NEXT
1750 LOCATE 1,1: GOTO 1570
1760 FILTERNO=POSITION
1770 GOSUB 3900: GOTO 890 'drive the filter wheel to the position
1780 '
1790 '*****
1800 '
1810 ' Main Program
1820 '
1830 '*****
1840 '
1850 COLOR 15,9
1860 IF FILTERNO <1 OR FILTERNO >MAX THEN 2460
1870 IF TIMES<>0 THEN 1910
1880 GOSUB 3050
1890 LOCATE 6,6: PRINT" Now is SAMPLING through Filter
No.":FILTERNO;".....": WL$(FILTERNO)
1900 IF FILTERNO <1 OR FILTERNO >MAX THEN 2960
1910 GOSUB 3900
1920 BEEP
1930 POSITION=FILTERNO
1940 FOR I=0 TO 2500: NEXT I
1950 '
1960 ' sampling
1970 '
1980 '
1990 LTIMER=&H718 '9513A timer data port address
2000 CALL LABPAC(LTIMER, RESULT, TIINIT) 'initialize timers
2010 CHN=1: START=300: FINISH=1100 'CHN--input channel;
START--pre-trigger; FINISH--post-trigger
2020 SWTIMER=1: MODE=13: VALUE=1 'SWTIMER--the chosen timer;
MODE--sampling frequency; VALUE--frequency divisor
2030 CALL LABPAC(SWTIMER, MODE, VALUE, RESULT, TIST) 'start the
counting/timing
2040 FOR I=0 TO SAMPLE-1
2050 CALL LABPAC(CHN, START, FINISH, RESULT, AISC) 'waiting for a
rising edge trigger
2060 INTMASK=&H81: NSWEEPS=200: NCHANS=1: AICHAN(0)=0

```



```

'NSWEEPS--sampling #; NCHANS--# of sampling channels;
'AICHAN()--analog input channel array
2070 CALL LABPAC(INTMASK, VALUE, INTCLR) 'mask hardware interrupts
2080 CALL LABPAC(SWTIMER, NSWEEPS, NCHANS, AICHAN(0), AIBUFF(0),
RESULT, AIMAX) 'high-rate sampling; AIBUFF()--raw data array from
one cycle
2090 CALL LABPAC(VALUE, VALUE, INTSET) 'unmask hardware interrupts
2100 DDDD(I)=AIBUFF(90-1) 'transfer the 90th (or 9msec delay) data
to a new array DDDD()
2110 NEXT I
2120 '
2130 '
2140 '
2150 '
2160 ' Statistics
2170 '
2180 SUM!=0
2190 IF FILTERNO <> ARPOS THEN 2260
2200 COUNT1=0: COUNT2=0: WARNFL=0 'WARNFL--too-high(>9.5volts)/low
(<4.0 volts) warning flag of argon intensity
2210 FOR I=0 TO SAMPLE-1
2220 IF DDDD(I)/409.6>9.5 THEN COUNT1=COUNT1+1 'COUNT1 &
2--counters
2230 IF DDDD(I)/409.6<4! THEN COUNT2=COUNT2+1
2240 NEXT
2250 IF COUNT1>20 OR COUNT2>20 THEN WARNFL=1
2260 FOR I=0 TO SAMPLE-1
2270 SUM!=SUM!+DDDD(I)
2280 NEXT I
2290 AVERAGE!=SUM!/SAMPLE
2300 SD!=0 'SD!--standard deviation
2310 FOR J=0 TO SAMPLE-1
2320 V!(J)=DDDD(J)-AVERAGE!
2330 SD!=SD!+V!(J)^2
2340 NEXT J
2350 SIGMA!=SQR(SD!/SAMPLE) 'SIGMA!--mean square error
2360 IF TIMES<>0 THEN 2390
2370 LOCATE 13, 30: PRINT" AVERAGE =";AVERAGE!/409.6
2380 LOCATE 15, 30: PRINT" Standard Error =";SIGMA!
2390 IF FILTERNO<>1 THEN 2410
2400 AR!(P)=AVERAGE!/409.6: ARE!(P)=SIGMA!/409.6
2410 IF FILTERNO<>2 THEN 2430
2420 LI!(P)=AVERAGE!/409.6: LIE!(P)=SIGMA!/409.6
2430 IF FILTERNO<>3 THEN 2450
2440 H!(P)=AVERAGE!/409.6: HE!(P)=SIGMA!/409.6
2450 FILTERNO=FILTERNO+1: GOTO 1860
2460 FILTERNO=1 'reset filter position
2470 IF AR!(P)-LI!(P)>.1 THEN 2540 'check if the filter controller
is in "COMPUTER" mode and "ON"
2480 GOSUB 3050
2490 LOCATE 10,20:PRINT"Please check Filter-Driver (on/off)"
2500 LOCATE 15,24:PRINT"Press any key to continue"

```

```

2510 RATIO!(P)=0
2520 IF INKEY$="" THEN 2520
2530 CLS: DRCOFL=1
2540 RATIO!(P)=(H!(P)-LI!(P))/(AR!(P)-LI!(P)) 'calculate the
relative hydrogen ratio
2550 RATIO2!(P)=(AR!(P)-LI!(P))/LI!(P) 'calculate the relative
argon intensity
2560 IF EXITFL=1 OR DRCOFL=1 THEN 2580
2570 IF TIMES <> 0 THEN 2600
2580 GOSUB 3410 'draw a coordinator
2590 DRCOFL=0: EXITFL=0
2600 P2=P 'P--present pointer of the data structure
2610 IF TIMES>MAXT THEN 2650
2620 P1=P 'P1, P2-- temporary pointers
2630 GOSUB 3730 'draw a rectangle on the histogram
2640 P=P2: GOTO 2730
2650 IF FLAG1<>0 THEN GOSUB 3850 'if full, clean the screen to
scroll
2660 FOR P1=0 TO MAXT-1
2670 P=P+1: IF P>MAXT THEN P=0
2680 GOSUB 3730
2690 NEXT
2700 P1=MAXT
2710 P=P2
2720 GOSUB 3730
2730 LOCATE 17,22:PRINT"Volts          Ratio          H (ppm)"
2740 LOCATE 19,17
2750 PRINT"Ar":LOCATE 20,16:PRINT"Bkg"
2760 LOCATE 21,17:PRINT"H"
2770 LOCATE 19,22
2780 PRINT USING"###.###";AR!(P)
2790 LOCATE 20,22
2800 IF FLAG2=1 THEN 2830
2810 IF WARNFL=1 THEN LINE(170,265)-(220,248),12,B ELSE
LINE(170,265)-(220,248),0,B
2820 GOTO 2840
2830 IF WARNFL=1 THEN LINE(170,151)-(220,142),1,B ELSE
LINE(170,151)-(220,142),0,B
2840 PRINT USING"###.###";LI!(P)
2850 LOCATE 21,22
2860 PRINT USING"###.###";H!(P)
2870 LOCATE 20,50
2880 IF HPPM!<=2 OR HPPM!>=500 THEN 2882 ELSE 2886
2882 IF HPPM!<=2 THEN PRINT " 0": GOTO 2890
2884 IF HPPM!>=500 THEN PRINT "500": GOTO 2890
2886 PRINT USING "###."; HPPM!
2890 LOCATE 20,36: IF RATIO!(P) <=0 THEN PRINT "0.00" ELSE PRINT
USING"###.###";RATIO!(P)
2900 LOCATE 23,30:PRINT"Press Any Key to Exit"
2910 IF INKEY$<>"" THEN 2970 'check if there are any interrupts
from the keyboard
2920 IF TIMES <MAXT THEN 2940 'check if full on the histogram

```

```

2930 FLAG1=1
2940 TIMES=TIMES+1:P=P+1: IF P>=MAXT+1 THEN P=0 'regulate the
pointer P
2950 FILTERNO=1: BEEP: GOTO 1860 'reset the filter position
2960 CLS: CALL LABPAC (RESULT, LRESET)
2970 GOSUB 3050
2980 LOCATE 11,26:PRINT" Exit to DOS (Y/N)"; 'process the
interrupts
2990 ROW=CSRLIN: COL=POS(0): INPUT KEE$
3000 IF KEE$="y" OR KEE$="Y" THEN SYSTEM
3010 IF KEE$="n" OR KEE$="N" THEN 3020 ELSE 3030
3020 EXITFL=1: GOTO 900
3030 LOCATE 13,28: PRINT"Please input again." : LOCATE ROW, COL:
GOTO 2990
3040 END
3050 '*****
3060 '
3070 '          Sets of SubPrograms
3080 '
3090 '*****
3100 '
3110 '
3120 ' Clean the screen and output double line border around screen
3130 '
3140 CLS: LOCATE 1,2,0: PRINT CHR$(201);
3150 FOR I=3 TO 78: PRINT CHR$(205);: NEXT
3160 PRINT CHR$(187);
3170 FOR I=2 TO 23
3180 LOCATE I, 2: PRINT CHR$(186);: LOCATE I,79: PRINT CHR$(186);
3190 NEXT
3200 LOCATE 24,2: PRINT CHR$(200);
3210 FOR I=3 TO 34: PRINT CHR$(205);: NEXT
3220 PRINT" ** Hydrogen Detection (c) 1992 by UTEP ** ";
3230 PRINT CHR$(205); CHR$(188);
3240 RETURN
3250 '
3260 ' Get a menu choice [0-high]; [Esc]->0, F1-F9->1-9
3270 '
3280 LOCATE 20,2,0: PRINT BLANK$;
3290 IF FTYPE<0 THEN 3330 ELSE IF SWEEPS(FTYPE)=0 THEN 3330
3300 CHOICE=-1: CALL LABPAC(CHOICE, RESULT, STAT(FTYPE))
3310 IF RESULT=0 THEN SWEEPS(FTYPE)=0
3320 LOCATE 20,32: PRINT USING "#### sweeps left"; RESULT;
3330 CHOICE$=INKEY$: IF LEN(CHOICE$)=0 THEN 3290
3340 IF CHOICE$=CHR$(27) THEN CHOICE=0: RETURN
3350 CHOICE=ASC(RIGHT$(CHOICE$,1))-38-10*LEN(CHOICE$)
3360 IF CHOICE>HIGH OR CHOICE<0 THEN BEEP: GOTO 3290
3370 RETURN
3380 '
3390 '          Draw a coordinate
3400 '
3410 CLS

```

```

3420 IF FLAG2=1 THEN 3440
3430 SCREEN 9:COLOR 15,9: GOTO 3450
3440 SCREEN 2
3450 SLOPEY=(YTOP-YBOT)/500: SLOPEX=(XRIGHT-XLEFT)/8
3460 LOCATE 6,1: PRINT"H/ppm"
3470 LOCATE 12,6:PRINT"0"
3480 LOCATE 10,4:PRINT"100"
3490 LOCATE 8,4:PRINT"200"
3500 LOCATE 4,4:PRINT"400"
3510 LOCATE 2,4:PRINT"500"
3520 LOCATE 14, 34: PRINT"TIME SEQUENCE
3530 FOR I= 0 TO MAXT
3540 LOCATE 13, 8+4*I: PRINT I+1;
3550 NEXT
3560 FOR I=7 TO MAXL
3570 LOCATE 12, I
3580 IF (I MOD 4)=3 AND I <>7 THEN 3600
3590 PRINT CHR$(196);: GOTO 3610
3600 PRINT CHR$(193);
3610 NEXT
3620 FOR J=1 TO 11
3630 LOCATE J,7
3640 IF (J MOD 2)=0 THEN 3660
3650 PRINT CHR$(179);: GOTO 3670
3660 PRINT CHR$(195)
3670 NEXT J
3680 LOCATE 12,7: PRINT CHR$(192);
3690 RETURN
3700 '
3710 '   Draw a rectangle
3720 '
3730 SLOPEY!=(YTOP-YBOT)/500: SLOPEX!=(XRIGHT-XLEFT)/8
3740 HPPM!=-182.12+RATIO!(P)*2068.68      'calibration curve of
hydrogen contents in ppm
3742 IF HPPM! >=0 AND HPPM! <=500 THEN Y=HPPM!
3744 IF HPPM! <0 THEN Y=0
3746 IF HPPM! >500 THEN Y=500
3750 X1=XLEFT+8+SLOPEX!*P1: Y2=YBOT+SLOPEY!*Y: YC=YBOT+SLOPEY!*Y0
3760 LINE(X1,YBOT-1)-(X1+16, Y2),,BF
3770 IF Y2 > YC THEN 3810
3780 IF FLAG2=1 THEN 3800
3790 LINE(X1,YC)-(X1+16,Y2),2,BF: GOTO 3810
3800 LINE(X1,YC)-(X1+16,Y2),,B
3810 RETURN
3820 '
3830 '   Clear to prepare rotation
3840 '
3850 FOR I =0 TO MAXT
3860 A1=XLEFT+8+I*32: A2=A1+18
3870 LINE(A1,YBOT-1)-(A2,0),0,BF
3880 NEXT
3890 RETURN

```

```
3900 '  
3910 '      Drive filter disk  
3920 '  
3930 OUT PORTADDR+3, 130  
3940 OUT PORTADDR+2, 255  
3950 OUT PORTADDR+3, 10  
3960 OUT PORTADDR+3, 2*(FILTERNO-1)  
3970 OUT PORTADDR+3, 14  
3980 FOR I=1 TO 100: NEXT  
3990 OUT PORTADDR+3, 15  
4000 RETURN
```

## APPENDIX G TECHNICAL INFORMATION

## HCMS System:

Department of Metallurgical and Materials Engineering  
University of Texas at El Paso  
El Paso, TX 79968  
TEL: (915)747-6933  
FAX: (915)747-5616

## Optical Elements:

ORIEL CORPORATION  
250 Long Beach Boulevard  
P. O. Box 872  
Stratford, CT 06497  
TEL.: (203)377-8282  
FAX: (203)378-2457  
TELEX: 4750361

## A/D Boards:

Technical Support Department  
SCIENTIFIC SOLUTIONS, INC.  
6225 Cochran Road  
Solon, OH 44139-3377  
TEL.: (216)349-4030  
FAX: (216)349-0851  
TELEX: 466692